

Biomass

STRATEGIC VALUE ANALYSIS

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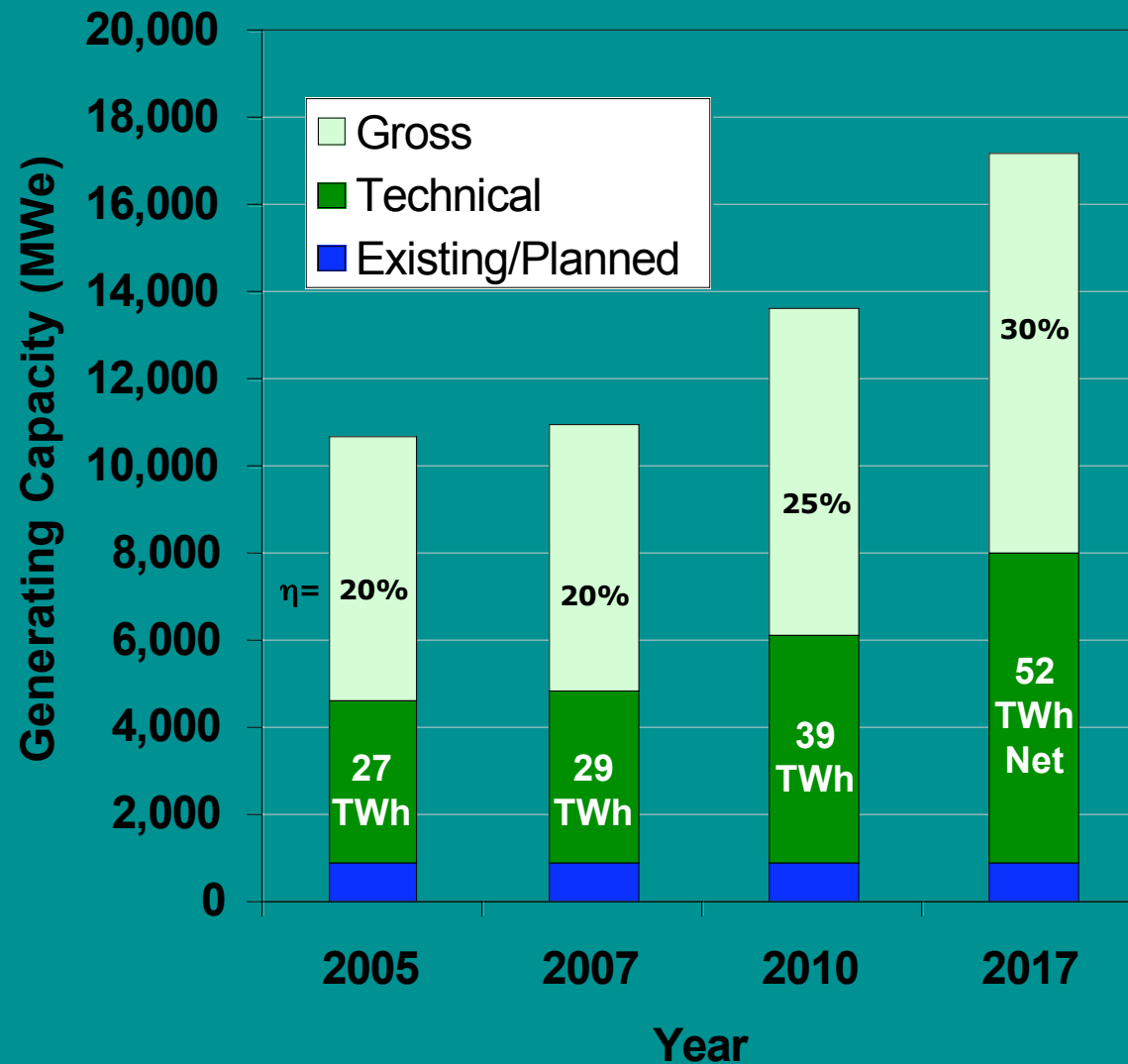
Zhiqin Zhang

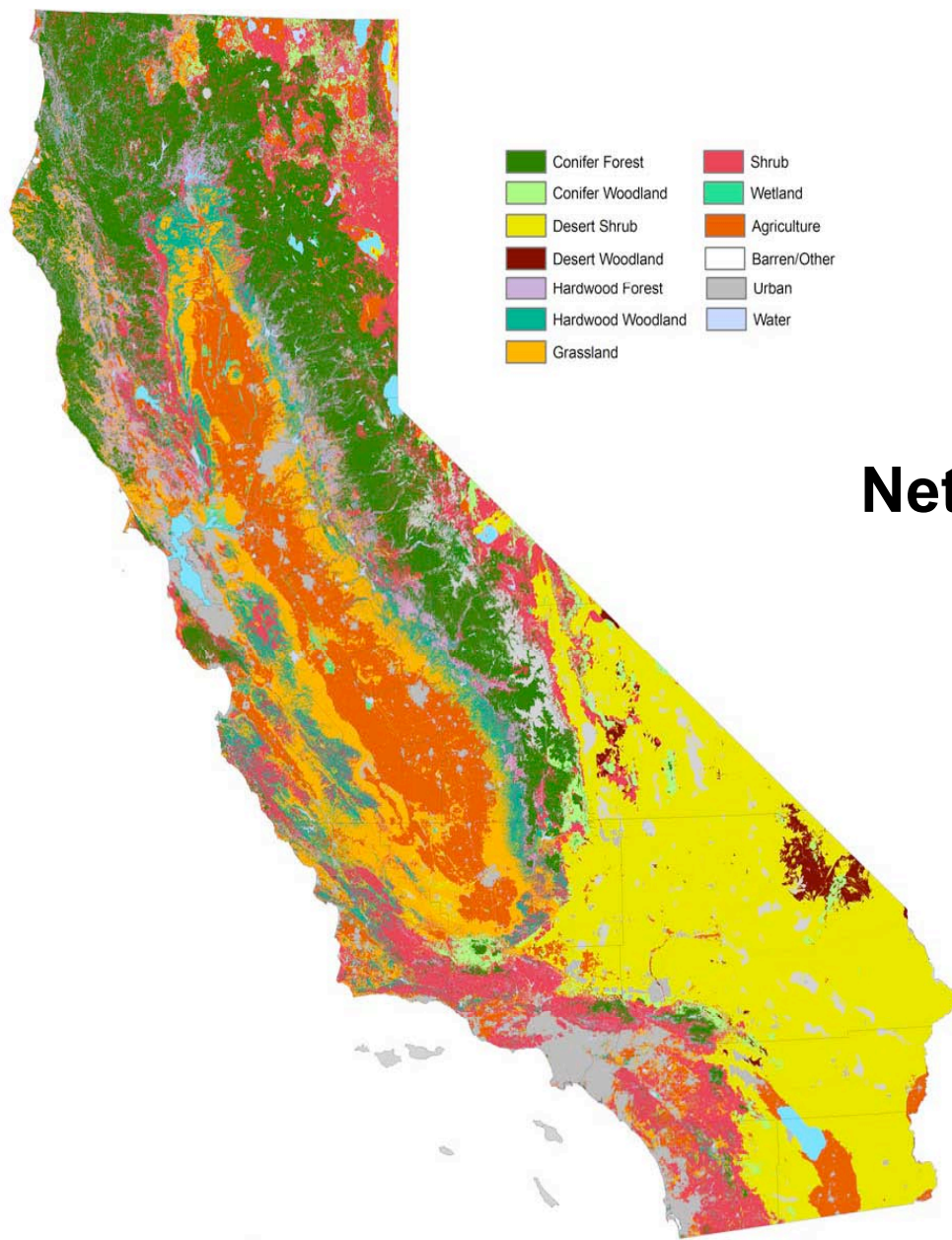
Energy Generation Research Office

July 1, 2005 IEPR Workshop



Potential Generating Capacity from Biomass in California 2005-2017





Biomass SVA Results

2010

2017

**Net Technical
Potential**

5,217 MW

7,086 MW

**Economic
Potential**

228 MW

1,334 MW

No Transmission
Upgrades

Biomass Energy Conversion Pathways

Biomass Resources

Agricultural residues

Forest residues

Municipal solid waste

Conversion Pathways

Thermo-chemical

- Combustion

Fluidized bed combustion
Stoker

- Gasification

BIGCC

Bio-chemical

- Anaerobic Digestion

Landfill gas
Dairy waste
Wastewater

Markets/Products

Electricity

Heat/Steam

Fuels

Chemicals

Methanol

Ethanol

Hydrogen

Biosynthesis

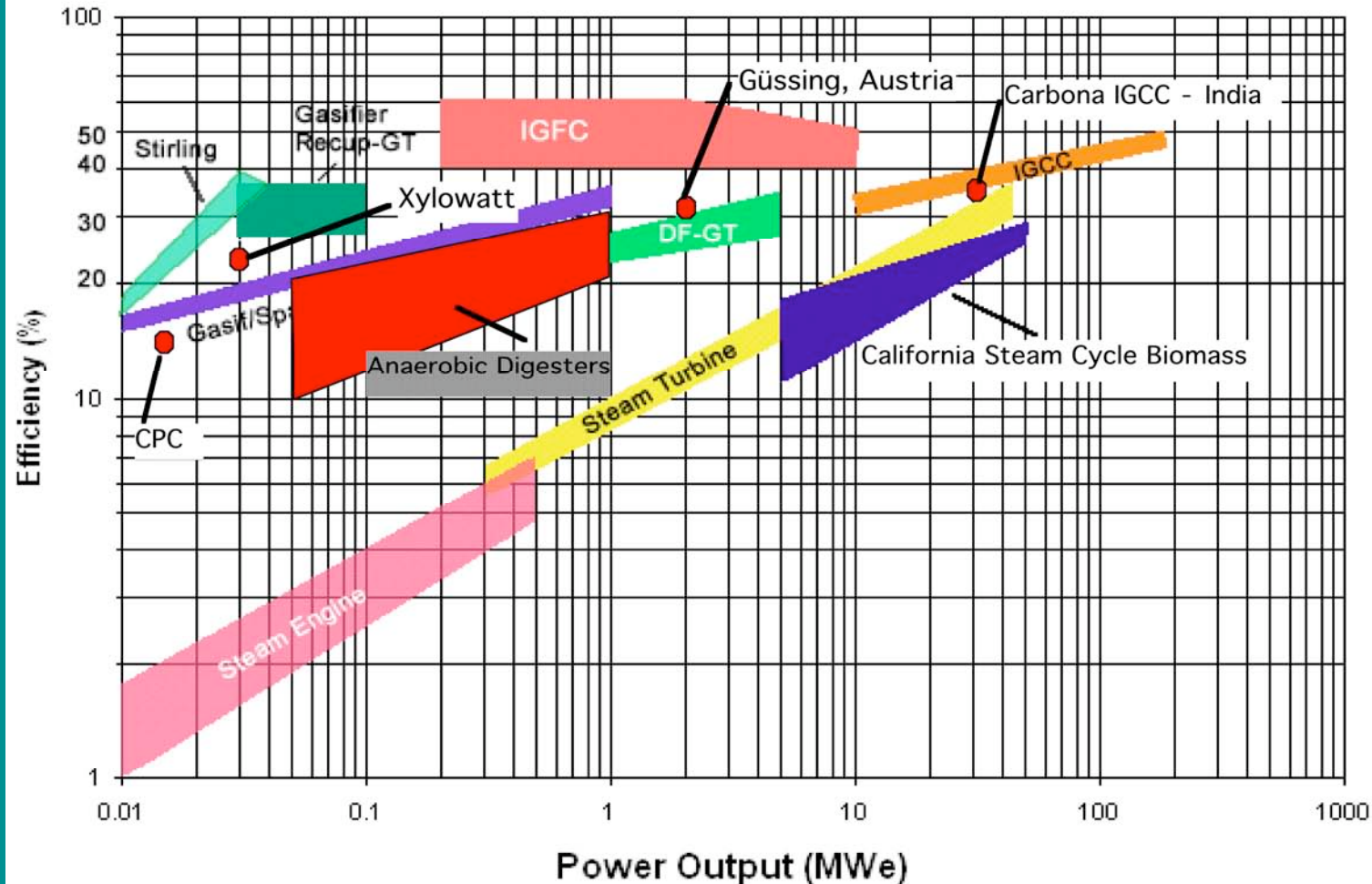
Gas

Acids

Other Value-

Added Products⁴

Performance Trends



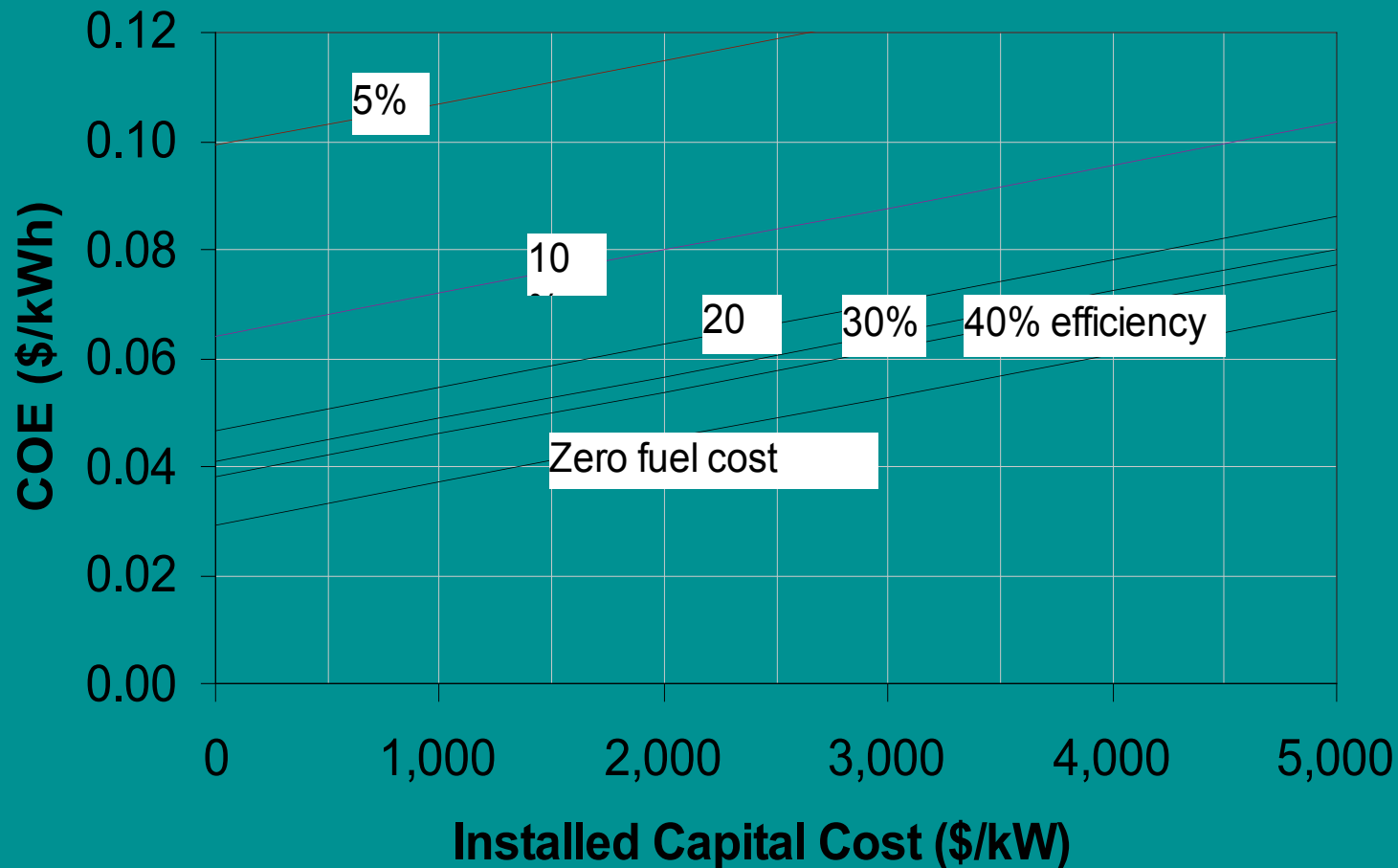
IGFC – Integrated Gasifier Fuel Cell

DF-GT – Direct Fired Gas Turbine (simple cycle)

IGCC – Integrated Gasifier Combined Cycle

Efficiency vs net electrical power output for several prime movers
(Adapted from R.P. Overend. 1998)

Cost Trends



Levelized cost of energy (LCOE, \$/kWh in constant 2004 dollars) for electricity from biomass.
Fuel cost = \$20/dry ton except as indicated.

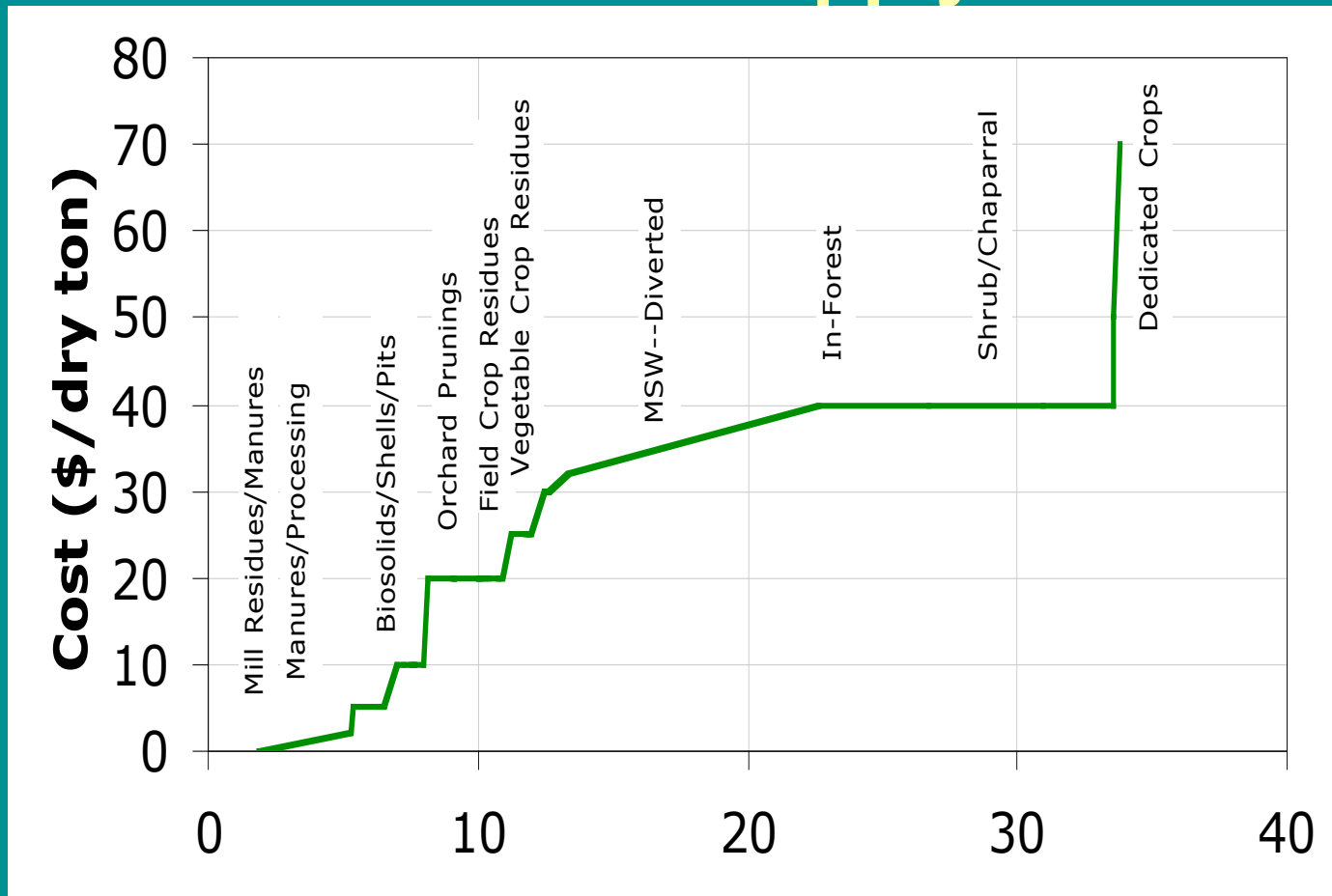
Assumes no return on equity (no profit) and no capacity payments.

With fixed O&M cost, COE for zero fuel cost is independent of efficiency at any capital cost.

Addition of 15% rate of return for 25% equity adds \$0.015/kWh to the cost of energy.

(Adopted from California Biomass Collaborative White Paper, April 2005)

Biomass Resource Supply Cost Curve



Estimated overall statewide biomass resource cost curve, 2005 technical resource base (excludes storage and on-site processing and handling costs).

(Adopted from California Biomass Collaborative White Paper, April 2005)

Economics of Biomass to Energy Conversion Technologies

Developed Economic Cost Models: Revenue Requirement Approach

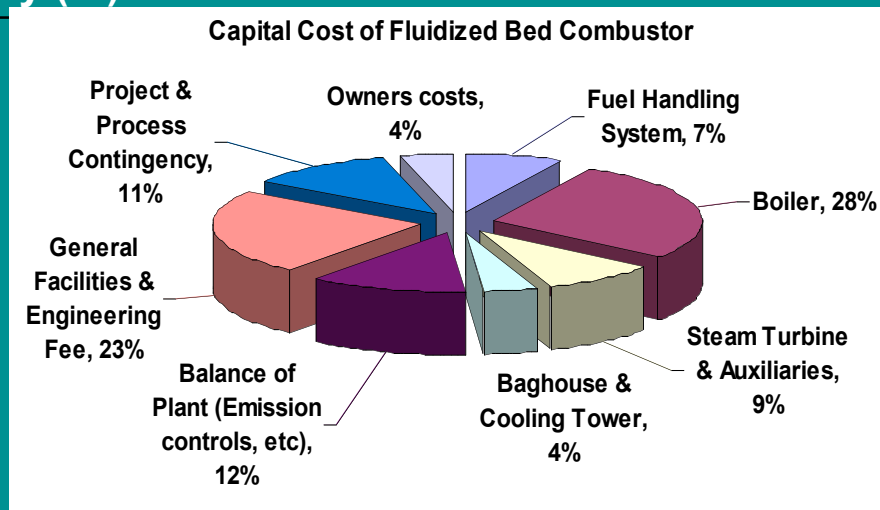
- Models calculate the levelized cost of electricity (LCOE) in current dollar and constant dollar*
- Models calculate LCOE's with and without PTC for years 2005, 2010 and 2017*

General Assumptions:

- Economic life: 20 years for all technologies*
- Federal tax rate = 34%*
- State tax rate = 6.65%*
- Production tax credit = \$0.009/kWh*
- Debt ratio= 67%*
- Equity Ratio = 33%*
- Interest rate on debt = 8.4%*
- Cost of equity = 16%*
- General inflation rate = 2.8%*
- Escalation rates for O&M and other expenses = 2.8%*
- ACRS depreciation (5 yr property)*
- Capacity payments = \$166/kW-yr*
- Fuel cost = \$20/BDT to \$40/BDT depending on the fuels*

Assumptions: Fluidized bed combustor

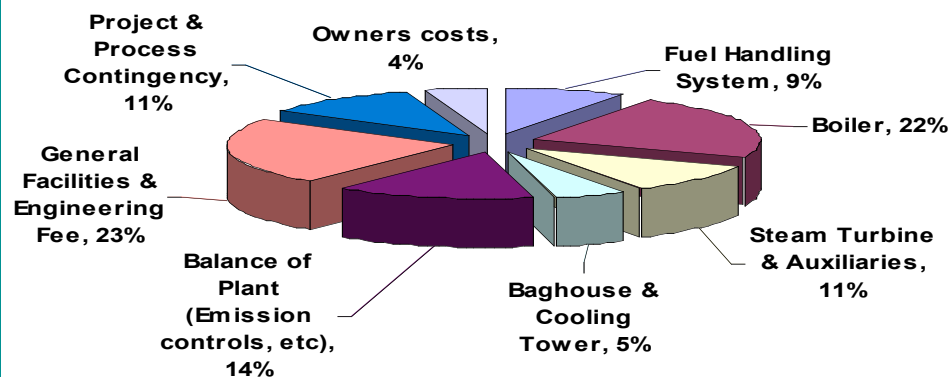
Technology	25 MW Fluidized Bed Combustor			
Year	2005	2007	2010	2017
Installed Capital Cost (\$/kW)				
Total Capital Cost	2,800	2,700	2,400	2,200
Operation and Maintenance Cost (\$/kW-yr)				
Fuel Cost (\$/BDT)*	22.0	22.0	20.00	20.00
Total Non-Fuel Expenses	232	227	225	220
Total Expenses Including Fuel	391	386	340	316
Capacity Factor (%)	85	85	85	85
Net Station Efficiency (%)	20	20	25	30



Assumptions: Stoker Boiler

Technology	25 MW Stoker Boiler			
Year	2005	2007	2010	2017
Installed Capital Cost (\$/kW)				
Total Capital Cost	2400	2350	2200	2000
Operation and Maintenance Cost (\$/kW-yr)				
Fuel Cost (\$/t)	22.0	22.0	20.0	20.0
Total Non-Fuel Expenses	213	209	203	199
Total Expenses Including Fuel	372	368	318	295
Capacity Factor (%)	85	85	85	85
Net Station Efficiency (%)	20	20	25	30

Capital Costs of Stoker Boiler



Assumptions: Gasifier BIGCC

Technology	25 MW Gasifier (BIGCC)		
Year	2005	2010	2017
Installed Capital Cost (\$/kW)			
Total Facility Capital Cost	2,800	1,750	1,500
Operation and Maintenance Cost (\$/kW-yr)			
Biomass Fuel Cost (\$/t)	22.0	20	20
Total Non-Fuel Expenses	233	227	222
Total Expenses Including Fuel	386	371	358
Capacity Factor (%)	90	90	90
HHV Efficiency of Gasification System--Biomass to Clean Gas (%)	65	65	65
Net HHV Efficiency of Power Generation	34	36	38
Overall Net System Efficiency (%)	22.1	23.4	24.7

Assumptions: Landfill Gas to Energy

Technology	1000 kW Landfill Gas/Power Generation		
Year	2005	2010	2017
Installed Capital Cost (\$/kW)			
Total Facility Capital Cost	1,300	1,100	1,000
Operation and Maintenance Cost (\$/kW-yr)			
Landfill Gas Fuel Cost--if purchased	0	0	0
Total Expenses	125	116	111
Capacity Factor (%)	85	85	85
Net HHV Efficiency of Power Generation incl. Dual Fuel (%)	23	25	30

Assumptions: Dairy Waste to Energy

Technology	200 kW Dairy Waste - Biogas/Power Generation		
Year	2005	2010	2017
Installed Capital Cost (\$/kW)			
Total Facility Capital Cost	3,500	3,000	2,600
Operation and Maintenance Cost (\$/kW-yr)			
Fuel Cost (\$/t)	0	0	0
Total Expenses Including Fuel	300	240	150
Capacity Factor (%)	85	88	90
Net Efficiency--Biogas to Electricity (%)	23	27	30

Assumptions: Wastewater to Energy

Technology	1000 kW – Wastewater Biogas/Power Generation		
Year	2005	2010	2017
Installed Capital Cost (\$/kW)			
Total Facility Capital Cost	1,350	1,250	1,088
Operation and Maintenance Cost (\$/kW-yr)			
Fuel Cost (\$/t)	0	0	0
Total Expenses Including Fuel	175	171	168
Capacity Factor (%)	85	88	90
Net Efficiency--Biogas to Electricity (%)	23	27	30

LCOE in current dollar (\$/kWh)

		Capital Cost (\$/kW)			LCOE (2004 Current \$/kWh)					
Year		2005	2010	2017	2005		2010		2017	
Technology	Capacity				PTC	No PTC	PTC	No PTC	PTC	No PTC
Biomass Fluidized Bed*	25 MW	2,800	2,400	2,200	0.0819	0.0863	0.0673	0.0716	0.0602	0.0645
Stoker Boiler*	25 MW	2,400	2,200	2,000	0.0724	0.0768	0.0604	0.0648	0.0535	0.0579
Gasifier (BIGCC)*	25 MW	2,800	1,750	1,500	0.0973	0.1017	0.0790	0.0833	0.0733	0.0776
Dairy Waste** a	200 kW	3,500	3,000	2,600	0.0487	0.0531	0.0376	0.0419	0.0214	0.0257
Landfill Gas**	1 MW	1300	1100	1000	0.0369	0.0413	0.0323	0.0366	0.0298	0.0342
WasteWater**	1 MW	1,350	1,250	1,088	0.0458	0.0502	0.0419	0.0463	0.0379	0.0423

* Fuel cost = \$20/BDT - \$22/BDT ^a Dairy Waste include sale of heat/sludge/fertilizer

** Assumed Zero fuel cost

COST COMPETITIVENES

MARKET PRICE AND LCOE COMPARISONS

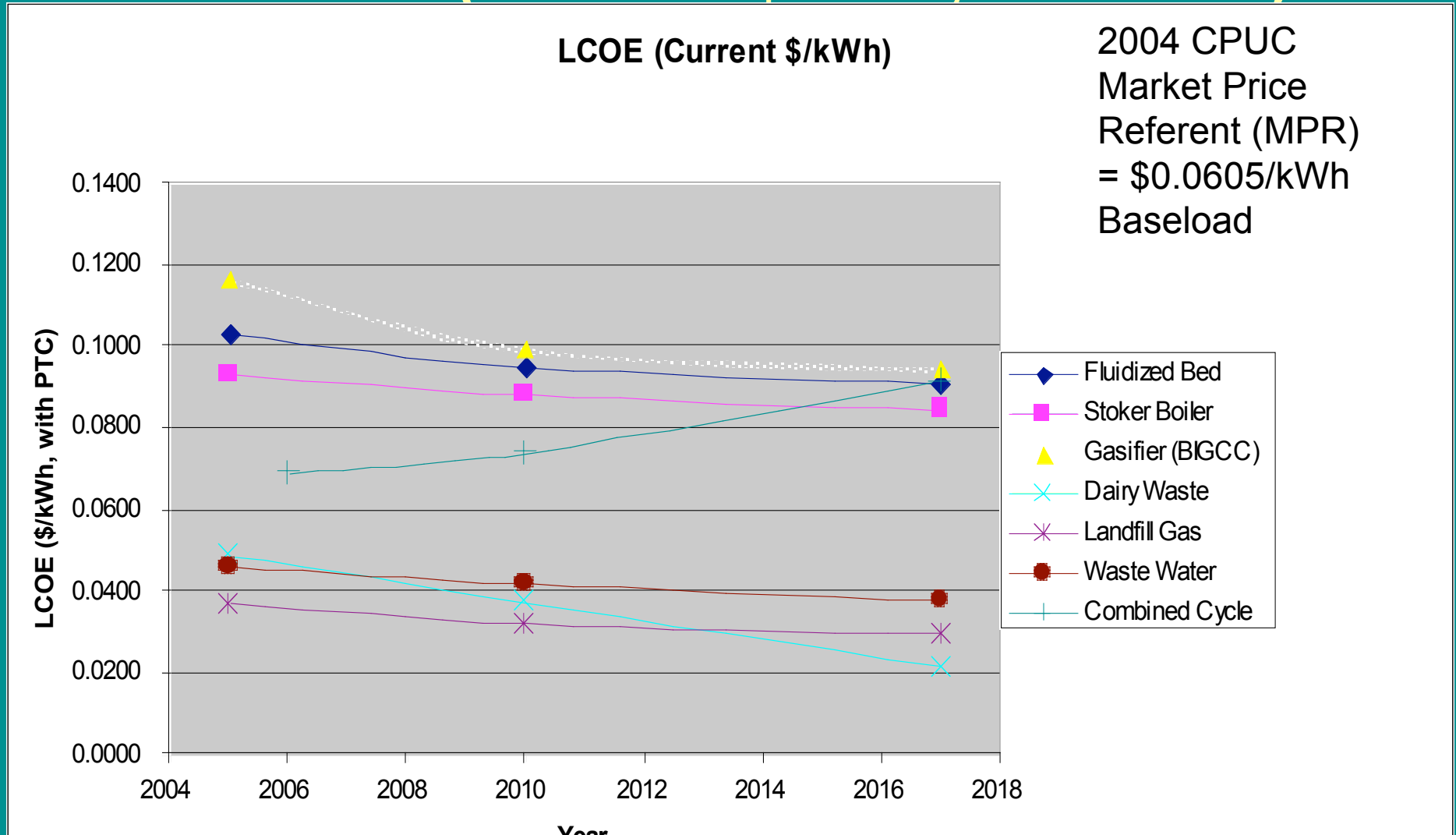
(Nominal dollars)

Year	Wholesale Price CEC 2003 Forecast ^a (\$/kWh)	Wholesale Price E-3 CPUC Forecast ^b (\$/kWh)	LCOE Combined Cycle ^b (\$/kWh)	2004 CPUC Market Price Referent (MPR) = \$0.0605/kWh Baseload = \$0.1141/kWh Peaking
2010	0.0426	0.063	0.0742	
2017	0.0587	0.0716	0.0915	

^a Electricity Infrastructure Assessment Report, May 2003 pp 15-19. 2003 CEC wholesale price forecast

^b The analysis for the E3-CPUC and Combined Cycle LCOE was completed by Energy and Environmental Economics, Inc. (E3) and is consistent with the methodology and inputs adopted for the California Public Utilities Commission Avoided Cost proceeding in Rulemaking 04-04-025, April 7, 2005. Details of the methodology and input assumptions can be found on the E3 website at http://www.ethree.com/cpuc_avoidedcosts.html.

LCOEs (nominal \$/kWh, with PTC)



25 MW sizes for fluidized bed, stoker & gasifier using forest fire threat fuels at \$40/BDT
 1 MW sizes for LFGTE and wastewater
 200 kW for dairy waste to energy

Biomass Economic Potential for 2010 & 2017

Biomass Fuels that were considered in the evaluation:

- Fire threat forest fuels

- Landfill gas

- Dairy Waste

- Wastewater

- Urban fuels

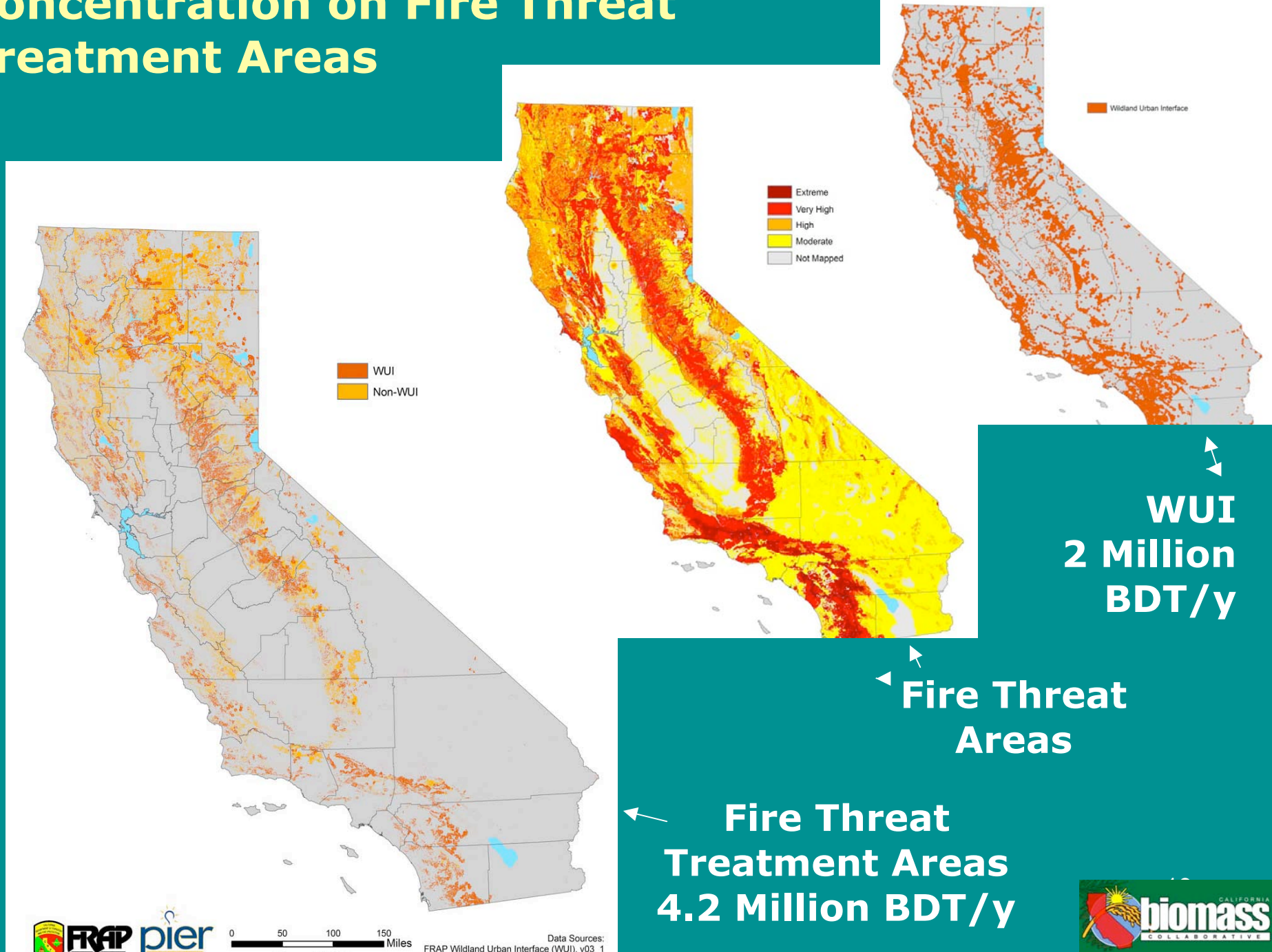
Economic Biomass Potential: assumed 25-mile radius of each substation and estimated BDT and MW generation

Selected substation were assumed to be the proximity of installation of biomass power system

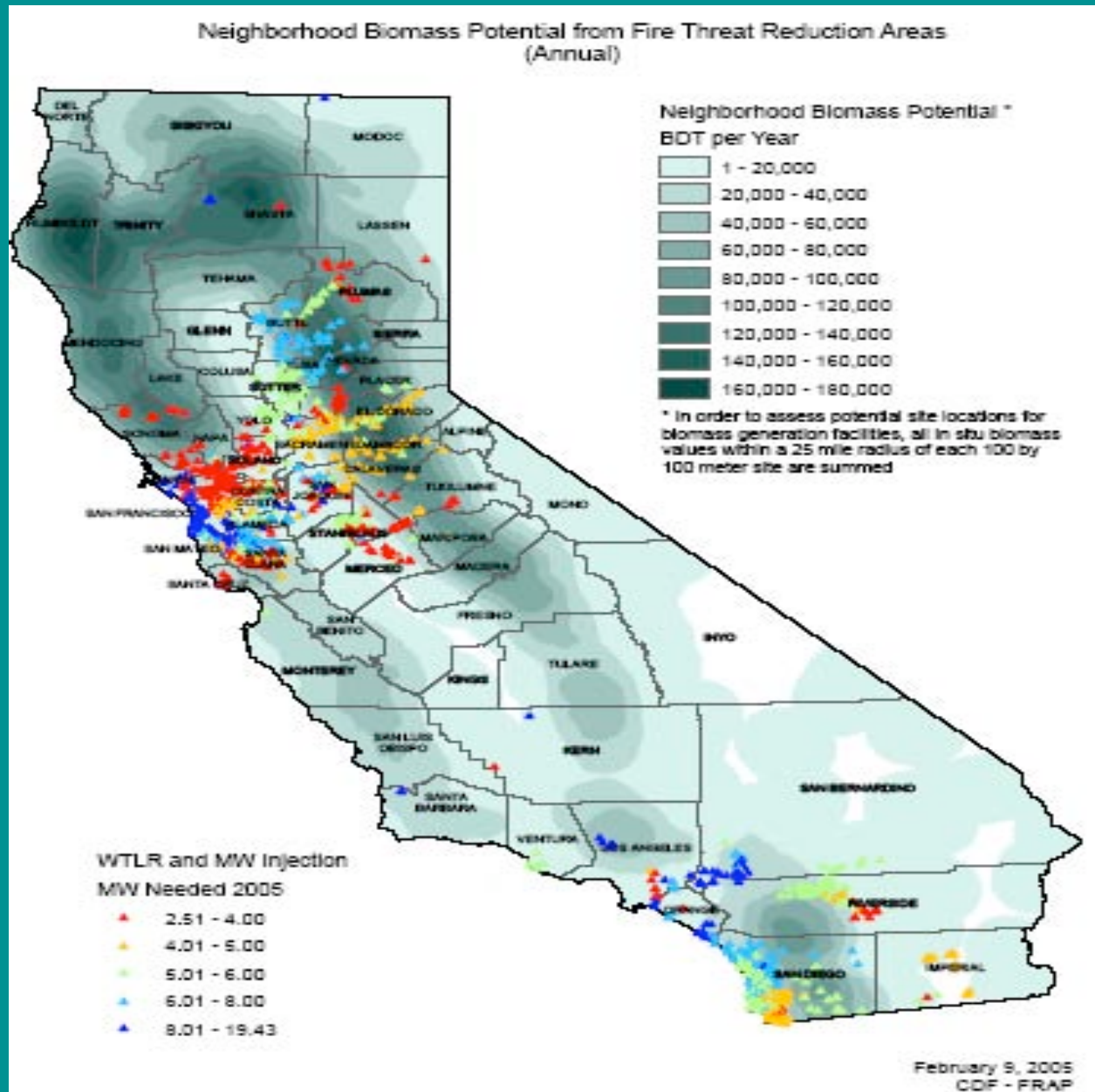
For forest fire threat areas a minimum of 120,000 BDT/yr was used as cutoff point

Assumed \$40/BDT for in forest fuels

Concentration on Fire Threat Treatment Areas



Biomass Potential for Fire Threat Reduction Areas



Fire Threat Reduction Areas: Power Flow Simulation Results

	2010 Base Case	2010 Case w/ 236 MW of Biomass	2010 Case w/ 393 MW of Biomass
Contingencies:	251	244	241
AMWCO:	11,347 MW	10,077 MW	10,138 MW
Impact Value:	--	-1,270 MW	-1,209 MW
Benefit Ratio:	--	-5.38	-3.07

Landfill Gas, Dairy, Wastewater and Urban Fuels: Power Flow Simulation Results

	2010	2017
	228 MW	952 MW
Contingencies:	327	489
AMWCO:	14,717 MW	23,975 MW
Impact Value:	-1,036 MW	- 4,070 MW
Benefit Ratio:	-4.54	- 4.47

2010 LCOE using forest fuels (current dollar): Not cost competitive

Name	County	Capacity (MW)	Trans mission Impact ratio	2010 No PTC	2010 with PTC	Market Price Referents
RDGE CBN	Humboldt	59	-3.07	0.0693	0.0649	0.0605
KEKAWAKA	Trinity	43	-3.07	0.0750	0.0707	0.0605
HGHLNDJ2	Lake	18	-3.07	0.1044	0.1000	0.0605
WILLITS	Mendocin o	35	-3.07	0.0799	0.0755	0.0605
MIRABEL	Sonoma	18	-3.07	0.1044	0.1000	0.0605
TRINITY	Trinity	26	-3.07	0.0889	0.0845	0.0605
CEDR CRK	Shasta	39	-3.07	0.0772	0.0728	0.0605
TYLER	Tehama	11	-3.07	0.1365	0.1321	0.0605
BIG MDWS	Plumas	32	-3.07	0.0823	0.0779	0.0605
GRSS VLY	Nevada	40	-3.07	0.0766	0.0722	0.0605
CH.STNJT	Tuolumne	21	-3.07	0.0972	0.0928	0.0605
JONESFRK	El Dorado	25	-3.07	0.0903	0.0859	0.0605
PARADISE	Butte	26	-3.07	0.0889	0.0845	0.0605
		393				

2010
LCOE of
Combined
Cycle

0.0742 \$/kWh
current dollar

2010 LCOE using Landfill Gas, Dairy waste, & Waste water (current dollar)

Biomass Resource	Capacity (MW)	Transmission Impact ratio	2010 No PTC	2010 with PTC	Market Price Referents
Dairy Manure (200 kW)*	21 MW	-4.54	0 .0419	0.0376	0.0605
Landfill Gas (1 MW)	162 MW	-4.54	0.0366	0.0323	0.0605
Waste water (1MW)	45 MW	-4.54	0.0463	0.0419	0.0605

*Dairy Waste include sale of heat/sludge/fertilizer

Statewide: 228 MW : cost competitive

2017 LCOE Fire Threat Forest Fuels* (current dollar)

Name	County	Capacity (MW)	Transmission Impact ratio	2017 No PTC	2017 with PTC	LCOE Combined cycle for 2017*
RDGE CBN	Humboldt	59	-3.0	0.0595	0.0552	0.09152
KEKAWAKA	Trinity	43	-3.0	0.0652	0.0608	0.09152
HGHLNDJ2	Lake	18	-3.0	0.0939	0.0895	0.09152
WILLITS	Mendocino	35	-3.0	0.0699	0.0655	0.09152
MIRABEL	Sonoma	18	-3.0	0.0939	0.0895	0.09152
TRINITY	Trinity	26	-3.0	0.0787	0.0743	0.09152
CEDR CRK	Shasta	39	-3.0	0.0673	0.0629	0.09152
TYLER	Tehama	11	-3.0	0.1253	0.1210	0.09152
BIG MDWS	Plumas	32	-3.0	0.0723	0.0679	0.09152
GRSS VLY	Nevada	40	-3.0	0.0667	0.0623	0.09152
CH.STNJT	Tuolumne	21	-3.0	0.0868	0.0824	0.09152
JONESFRK	El Dorado	25	-3.0	0.0800	0.0757	0.09152
PARADISE	Butte	26	-3.0	0.0787	0.0743	0.09152
		393				

*Assumed Fuel cost = \$40/BDT

Tehama site at 11 MW = not cost competitive
328 MW cost competitive by 2017

2017 LCOE Landfill Gas, Dairy Waste, Wastewater & Urban Fuels (current dollar)

Biomass Resource	Statewide Capacity (MW)	Transmission Impact ratio	2017 No PTC	2017with PTC	LCOE Combined cycle for 2017*
Dairy Manure (200 kW)	37	-4.5	0.0257	0.0214	0.09152
Landfill Gas (1 MW)	499	-4.5	0.0342	0.0298	0.09152
Waste water (1MW)	58	-4.5	0.0423	0.0379	0.09152
Urban Fuels	361	-4.5	0.0645	0.0602	0.09152

952 MW - cost competitive by 2017